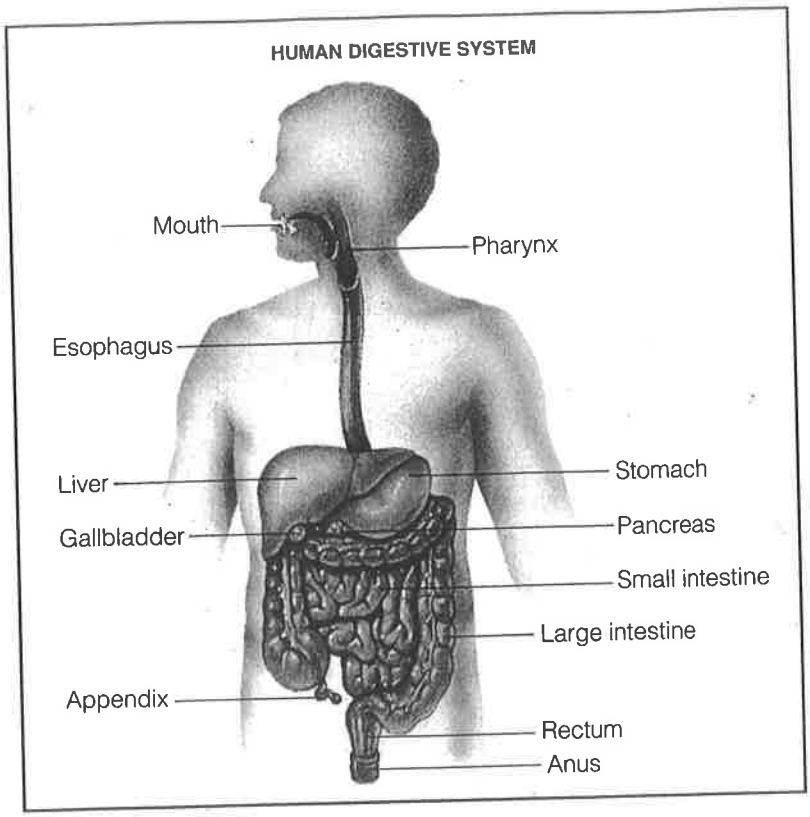
Figure 3–10 *The breaking down of food into simpler substances that can be used by the body is the work of the digestive system. The digestive system consists of a number of different organs. Through which organ does food enter the digestive system?*



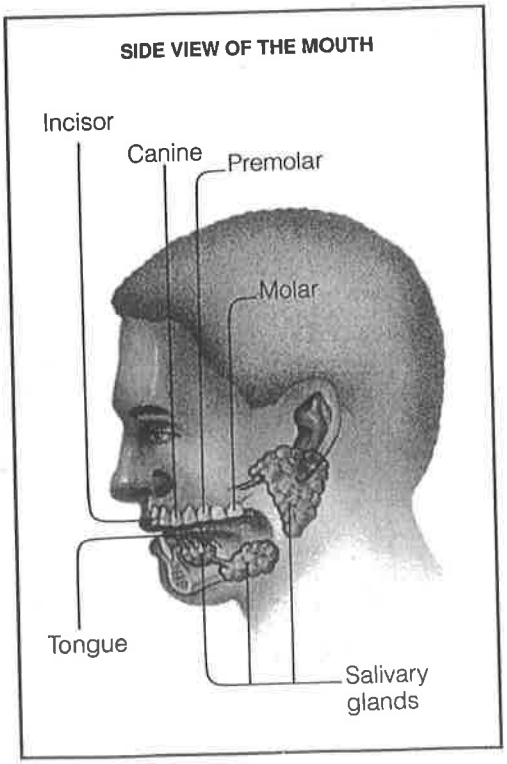


Figure 3–11 *Salivary glands, which are found in the mouth, produce saliva. Saliva contains the enzyme ptyalin. Which nutrient does ptyalin break down?*

The Mouth

Close your eyes and imagine your favorite food. Did your mouth water as you pictured something really delicious? Probably so. This response occurs because the mouth contains salivary (SAL-uh-vair-ee) glands. Salivary glands produce and release a liquid known as saliva (suh-LIGH-vuh). Seeing, smelling, or even thinking about food can increase the flow of saliva.

As you know from experience, saliva helps to moisten your food. But saliva has another important function. Saliva contains a chemical substance called **ptyalin** (TIGH-uh-lihn). Ptyalin breaks down some of the starches in food into sugars. You can actually detect this process by trying the following activity. Put a small piece of bread into your mouth and chew it for a few minutes. What happens? The bread begins to taste sweeter. Why? Bread is made mainly of starches, and starches are made of long chains of sugars. When ptyalin comes into contact with a starch, it begins to digest the starch, or break it down into sugars. The presence of these sugars makes the bread taste sweeter.

Figure 3–12 *The X-ray of the mouth shows the location of the four types of teeth: incisors, canines, premolars, and molars. The brighter areas in the teeth are the fillings. Where are the incisors located?*

Ptyalin belongs to a group of chemicals in your body known as **enzymes.** An enzyme helps to control a wide variety of chemical reactions, including the breaking down of foods into simpler substances. The digestion of foods by enzymes, such as ptyalin, is called chemical digestion. So although you may not have realized it, chemical digestion actually begins in your mouth!

Chemical digestion is not the only type of digestion that occurs in the mouth. Mechanical digestion, which is the physical action of breaking down food into smaller parts, also begins in the mouth. When you bite into your food, your incisors (ihn-SIGH-zerz), or front teeth, cut off a piece of the food. You then pull the food into your mouth with your lips and use your tongue to push it farther along into your mouth. Here the canines (KAY-nighnz), or eyeteeth, tear and shred the food while the flat-headed premolars and molars, or back teeth, grind and crush the food into small pieces.

Now that you have imagined your favorite food, think of the one you dislike most. The moment this food is in your mouth, something happens that makes you want to spit it out. If someone asked you why, you would probably say that the food tastes bad. Food tastes good or bad to you because there are taste buds on your tongue. Without taste buds, you would not be able to tell the difference between the food you dislike and the food you like.

Covering the surface of your tongue are small projections that give parts of the tongue a velvety

ACTIVITY DISCOVERING

How Sweet It Is

1. Obtain two baby-food jars with lids. Label one jar A and the other B.

2. Fill each jar with equal amounts of water.

3. Place a whole sugar cube into jar A and a crushed sugar cube into jar B.

4. Place the lid on each jar and carefully shake each jar about five times.

5. Place the jars on a flat surface where they can remain undisturbed. Observe the rate of solution, or the time it takes for the sugar to dissolve completely, in each jar.

Which jar had the faster rate of solution? Can you think of any other factors that would affect the rate of solution? How would you test for these factors?

■ Relate the results of your investigation to the importance of mechanical digestion.

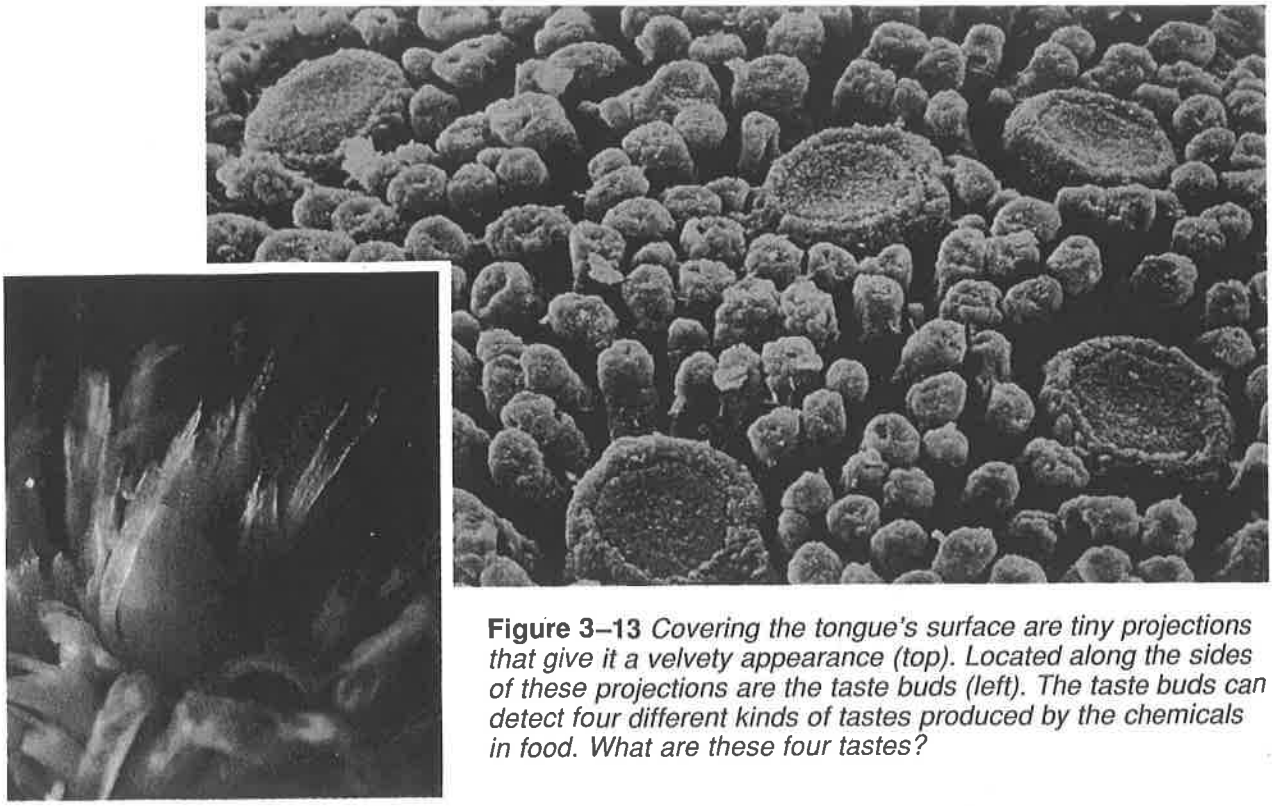


Figure 3–13 *Covering the tongue's surface are tiny projections that give it a velvety appearance (top). Located along the sides of these projections are the taste buds (left). The taste buds can detect four different kinds of tastes produced by the chemicals in food. What are these four tastes?*

appearance. See Figure 3–13. Your taste buds are found along the sides of these projections. There are four types of taste buds, each of which reacts to a different group of chemicals in food. The reactions between taste buds and food chemicals produce four kinds of tastes: sweet, sour, bitter, and salty. The flavor of food, however, does not come from taste alone. Flavor is a mixture of taste, texture, and odor. Anyone who has ever had a stuffed nose caused by a cold knows how important the sense of smell is to the flavor of food.

What happens once you have finished chewing your food? You swallow it, of course! When you swallow, smooth muscles near the back of your throat begin to force the food downward. As you may recall from Chapter 2, smooth muscles are involuntary muscles. This means that they can contract without your actively causing them to. As you swallow, a small flap of tissue called the epiglottis (ehp-uh-GLAHT-ihs) automatically closes over your windpipe. The windpipe is the tube through which the air you breathe reaches your lungs. When the epiglottis closes over the windpipe, it prevents food or water from moving into the windpipe—or "down the wrong pipe," as we say. After swallowing, the epiglottis moves back into place to allow air into the windpipe.

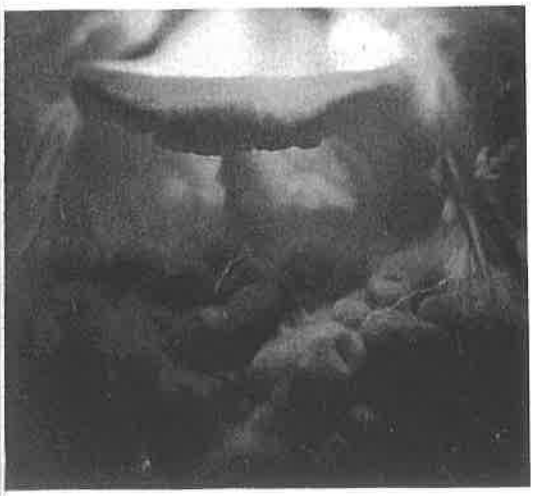


Figure 3–14 *The epiglottis, which is a flap of tissue, folds over the windpipe to keep food or water from going "down the wrong pipe."*

The Esophagus

After you swallow, smooth muscles force the food into a tube called the **esophagus** (ih-SAHF-uh-guhs). The word esophagus comes from a Greek word that means to carry what is eaten. And that is exactly what this 25-centimeter-long tube does as it transports food down into the next organ of the digestive system.

The esophagus, like most of the organs in your digestive system, is lined with slippery mucus. The mucus helps food travel through the digestive system easily. The movement of food through your esophagus takes about 12 seconds. However, mucus alone is not responsible for the speed of this trip. Waves of rhythmic muscular contractions, which begin as soon as food enters the esophagus, push food downward. These waves of contractions are called **peristalsis** (per-uh-STAHL-sihs). Peristalsis is so strong that it can force food through parts of your digestive system even if you are lying down. Because of peristalsis, a person can digest food even while floating upside down in the weightlessness of space.

ACTIVITY DISCOVERING

Simulating Peristalsis

1. Obtain a 40-cm piece of clear plastic tubing.

2. Hold the tubing vertically and insert a small bead into the top opening of the tubing. The bead should fit snugly into the tubing.

3. Pinch the tubing above the bead so that the bead is pushed down along the length of the tubing.

How does this action compare with peristalsis?

■ What action would you be simulating if you were to pinch the tubing below the small bead?

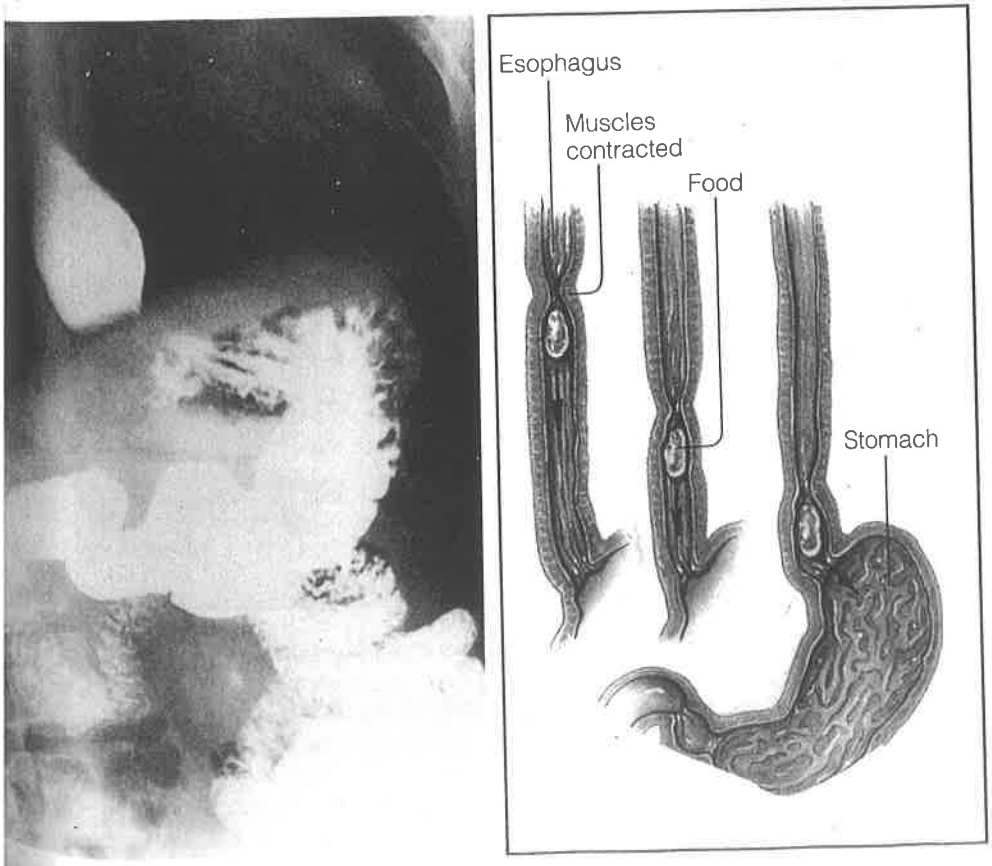


Figure 3–15 *Peristalsis is the waves of contractions that push food through parts of the digestive system. Use the diagram to identify the parts of the digestive system shown in the X-ray. Notice the vertebral column in the background.*

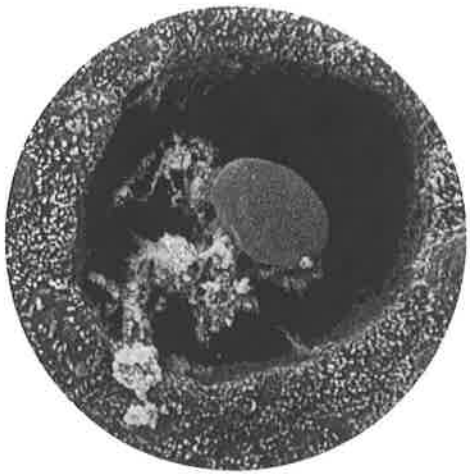


Figure 3–16 *To protect the stomach from the effects of hydrochloric acid, tiny pits secrete a layer of mucus, which appears yellow in the photograph. The single red blood cell floating out of the pit is thought to be a sign that the stomach has been irritated by a substance such as alcohol.*

The Stomach

After leaving the esophagus, the food enters a J-shaped organ called the **stomach.** Cells in the stomach wall release a fluid called gastric juice. Gastric juice contains the enzyme **pepsin,** hydrochloric acid, and thick, slippery mucus. If you were studying chemistry, you would learn that hydrochloric acid is a strong acid. This means that it is very reactive. In fact, the hydrochloric acid in your stomach is so reactive that if you could remove a drop of it and place it on a rug, it would burn a hole in the rug! The mucus, on the other hand, coats and protects the stomach wall. Can you see why such protection is necessary?

While food is in the stomach, it undergoes both mechanical digestion and chemical digestion. The contractions of the stomach muscles provide a kind of mechanical digestion as they churn the food and mix it with gastric juice. With the help of hydrochloric acid, pepsin breaks down some of the complex proteins in the food into simpler proteins. The action of pepsin on the proteins is a form of chemical digestion. Both of these types of digestion occur as peristalsis pushes the food toward the stomach's exit.

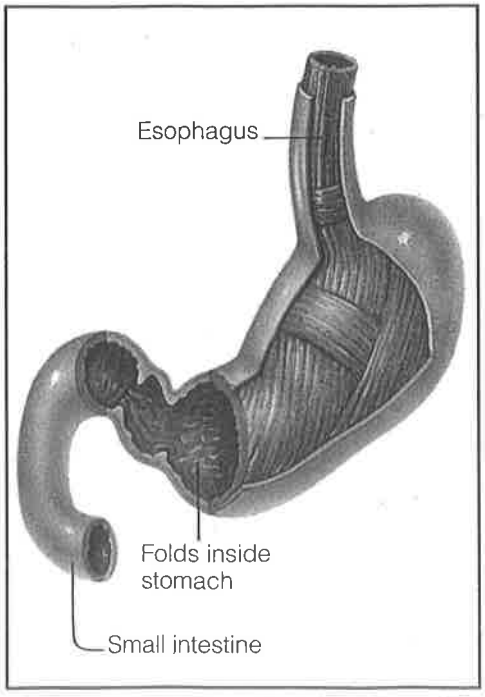


Figure 3–17 *The stomach wall consists of several layers of smooth muscles (left). When these muscles contract, food and gastric juice within the stomach are mixed together. Notice that the stomach's inner lining contains many folds (right). These folds will smooth out as the organ fills with food. What enzyme does gastric juice contain?*

The Small Intestine

The food moving out of your stomach is quite a bit different from the food that you placed in your mouth. After three to six hours in your stomach, muscle contractions and enzymes have changed the food into a soft, watery substance. In this form, the food is ready to move slowly into another organ of the digestive system—the **small intestine.** Although this organ is only 2.5 centimeters in diameter, it is more than 6 meters long. As in the esophagus and the stomach, food moves through the small intestine by peristalsis.

Although some chemical and mechanical digestion has already taken place in the mouth and the stomach, most digestion takes place in the small intestine. The cells lining the walls of the small intestine release an intestinal juice that contains several types of digestive enzymes.

Most chemical digestion that occurs in the small intestine takes place within the first 0.3 meter of this organ. Here, intestinal juice helps to break down food arriving from the stomach. This juice, however, does not work alone. It is helped by juices that are produced by two organs located near the small intestine. These organs are the **liver** and the **pancreas** (PAN-kree-uhs). Because food never actually passes

SOME DIGESTIVE ENZYMES

Digestive Juice	Digestive Enzyme	Works on	Changes It to
Saliva	Ptyalin	Starch	Complex sugars
Gastric	Pepsin	Protein	Simpler proteins
Pancreatic	Amylase Trypsin Lipase	Starch Proteins Fats	Complex sugars Simpler proteins Fatty acids and glycerol
Intestinal	Lactase, maltase, sucrase Peptidase Lipase	Complex sugars Simpler proteins Fats	Simple sugars Amino acids Fatty acids and glycerol

Figure 3–18 *According to this chart, which enzymes work on proteins? Which work on fats?*

ACTIVITY DOING

Enzymes

Enzymes speed up the rate of certain body reactions that would otherwise occur very slowly. During these reactions, the enzymes are not used up or changed in any way. Using reference materials in the library, look up the meaning of "substrate" and the "lock-and-key hypothesis." Using posterboard and colored construction paper, make a labeled diagram of this hypothesis. Present the diagram to the class.

What is the relationship between an enzyme and a substrate?

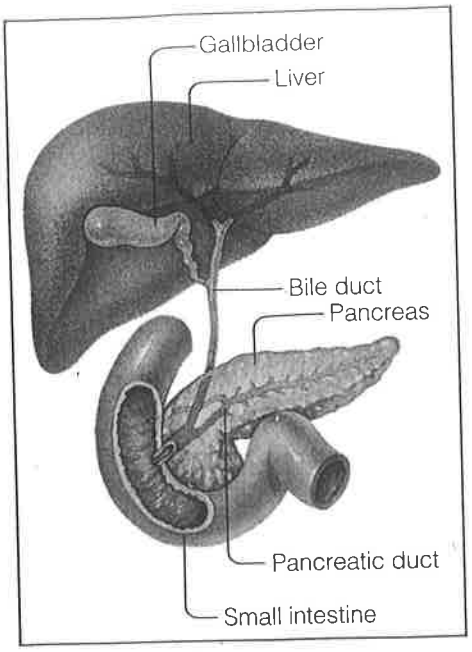


Figure 3–19 *The liver, pancreas, and gallbladder produce and store substances that are released into the small intestine to aid in the digestion of food.*

through the liver and the pancreas, these organs are considered to be digestive helpers.

THE LIVER Located to the right of the stomach is the liver, the body's largest and heaviest organ. One of its many important functions is to aid digestion by producing a substance called bile. Once bile is produced in the liver, it moves into the gallbladder, where it is stored until needed.

As food moves into the small intestine from the stomach, the gallbladder releases bile through a duct (tubelike structure) into the small intestine. Because bile is not an enzyme, it does not chemically digest foods. It does, however, help to break up large fat particles into smaller ones in much the same way a detergent breaks up grease. These smaller fat particles can then be digested easily by enzymes in the small intestine.

THE PANCREAS The pancreas is a soft triangular organ located between the stomach and the small intestine. The pancreas produces a substance called pancreatic juice, which is a mixture of several enzymes. These enzymes move into the small intestine at the same time the bile does and help to break down proteins, starches, and fats.

The pancreas also produces a substance called insulin, which is important in controlling the body's use of sugar. You will read more about the pancreas and insulin in Chapter 6.

ACTIVITY DISCOVERING

Do Oil and Water Mix?

1. Obtain two baby-food jars with lids. Place 5 mL of vegetable oil and 5 mL of water in each jar.

2. Cover both jars and gently shake them a few times. Then place the jars on a flat surface and observe what happens in each jar.

3. Remove the lid from one of the jars and add a few drops of liquid soap to the oil-and-water mixture. Repeat step 2.

Under what circumstances do oil and water mix?

- How does the action of liquid soap resemble the action of bile?

3–2 Section Review

1. Describe the process of digestion.
2. Compare mechanical and chemical digestion.
3. What is peristalsis? Why is it important?
4. Where does most of the digestion of food take place?
5. Why are the liver and the pancreas called digestive helpers rather than digestive organs?

Connection—*You and Your World*

6. Why is it important to chew your food thoroughly before swallowing it?

3–3 Absorption of Food

After a period of 3 to 5 hours, most of the food that is in the small intestine is digested. Proteins are broken down into individual amino acids. Carbohydrates (starches and sugars) are broken down into simple sugars. And fats are broken down into substances called fatty acids and glycerol. But before these nutrients can be used for energy, they must first be absorbed (taken in) by the bloodstream through the walls of the small intestine.

Guide for Reading

Focus on this question as you read.

▶ *What is the process of absorption?*

Absorption in the Small Intestine

The small intestine has an inner lining that looks something like wet velvet. This is because the inner lining of the small intestine is covered with millions of tiny fingerlike structures called **villi** (VIHL-igh; singular: villus, VIHL-uhs).

Digested food is absorbed through the villi into a network of blood vessels that carry the nutrients to all parts of the body. The presence of villi helps to increase the surface area of the small intestine, enabling more digested food to be absorbed faster than would be possible if the small intestine's walls were smooth. The villi contain tiny blood vessels that absorb and carry away the nutrients.

By the time the food is ready to leave the small intestine, it is basically free of nutrients, except for water. All the nutrients have been absorbed. What remains are undigested substances that include water and cellulose, a part of fruits and vegetables.

As the undigested food leaves the small intestine, it passes by a small finger-shaped organ called the appendix (uh-PEHN-diks). The appendix, which leads nowhere, has no known function. However, scientists suspect it may play a role in helping the body resist disease-causing bacteria and viruses. The only time that you may be aware of the appendix is when it becomes irritated, inflamed, or infected, causing appendicitis (uh-pehn-duh-SIGHT-ihs). The only cure for appendicitis is to remove the appendix by surgery as soon as possible.

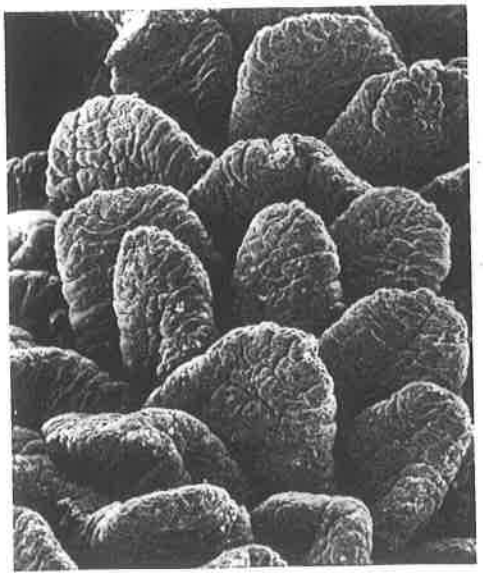
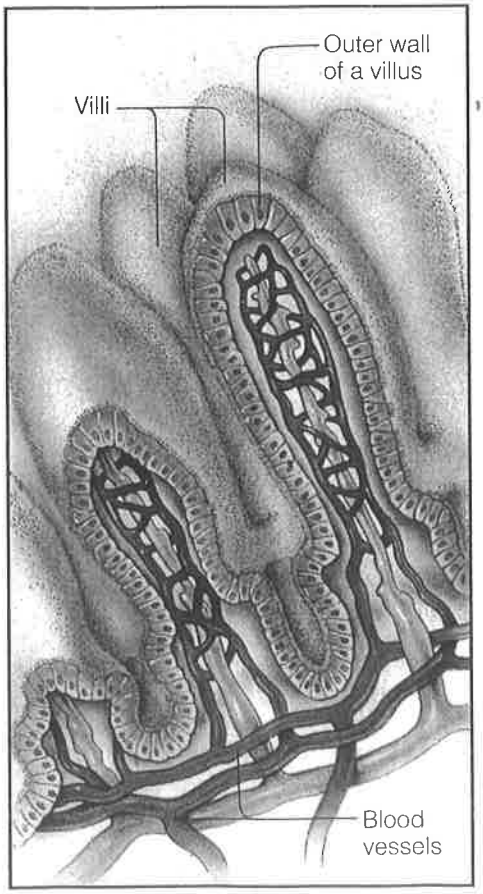


Figure 3–20 *These hills and ridges, which resemble part of a mountain range on the Earth's surface, are actually part of the small intestine. The tiny structures, called villi, line the inside of the small intestine. What is the function of the villi?*

Figure 3–21 *Notice the single layer of cells that cover each fingerlike villus in the photograph. The diagram shows what the inside of a villus looks like.*



Absorption in the Large Intestine

After leaving the small intestine, the undigested food passes into the **large intestine.** The large intestine is shaped like a horseshoe that fits over the coils of the small intestine. The large intestine is about 6.5 centimeters in diameter but only about 1.5 meters long. How do you think the large intestine got its name?

After spending about 18 to 24 hours in the large intestine, most of the water that is contained in the undigested food is absorbed. At the same time, helpful bacteria living in the large intestine make certain vitamins, such as K and two B vitamins, that are needed by the body.

Materials that are not absorbed in the large intestine form a solid waste. This solid waste is made up of dead bacteria, some fat and protein, undigested food roughage, dried-out parts of digestive juices, mucus, and discarded intestinal cells. A short tube at the end of the large intestine called the **rectum** stores this waste. Solid wastes are eliminated from the body through an opening at the end of the rectum called the **anus.**

Figure 3–22 *The large intestine forms an upside-down horseshoe that fits over the small intestine (left). Lining the inside of the large intestine are many tunnels that contain mucus-making cells (right).*